Increased Underwater Optical Imaging Performance Via Multiple Autonomous Underwater Vehicles

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LONG-TERM GOALS

The major long-term scientific goal of this program is to explore techniques for increasing the performance of underwater optical imaging systems.

OBJECTIVES

The main objective of this project is to explore the possibility of using Multiple Autonomous Underwater Vehicles for increasing the performance of underwater optical imaging systems. The main objective, in this context, is to simulate the potential benefits that multiple vehicles can have in increasing the range, imaging footprint, and potentially 3-dimensional applications that can be afforded using this new approach. This report details the Year 1 efforts that were focused on performing computer simulations in order to test a simple implementation of the idea.

APPROACH

In order to explore the utility of the MAUVIO concept we have been performing underwater computer optical image simulations. Over the last decades, we have used an underwater optical imaging program entitle UNCLES in order to simulate the output from a proposed configuration of lights and cameras. The program has, as input, the 3-dimensional locations of lights and cameras and their pointing angles in a Eulerian frame of reference. The lights are considered to be monochromatic, however, wide band illumination can be determined via repeated simulations at different narrow bands with the concomitant environmental characteristics. The lighting pattern can also be varied to correspond to either a narrow sheet like beam or a wide beam with arbitrary theta and phi beam widths being specified by an arbitrary radial dependent intensity pattern. The camera description includes the f# of the camera lens in addition to the focal length and the number of resolution elements. A reflectance map is input with an arbitrary reflectance profile that can be used to simulate either interesting images or a range of contrast values that the user expects to encounter in real situations.

Here we demonstrate the advantages of the MAUVIO concept via the comparison of two configurations of lights and cameras. One configuration corresponds to a single AUV where the camera is mounted on one end and the lights are mounted on the other end. The other configuration corresponds to the same camera location, however this time the illumination is provided by an AUV that is located closer to the target with a broad illumination pattern. Figure 1 shows the geometric

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location of the devices including the beam widths of the light sources and the size of the reflectance map.

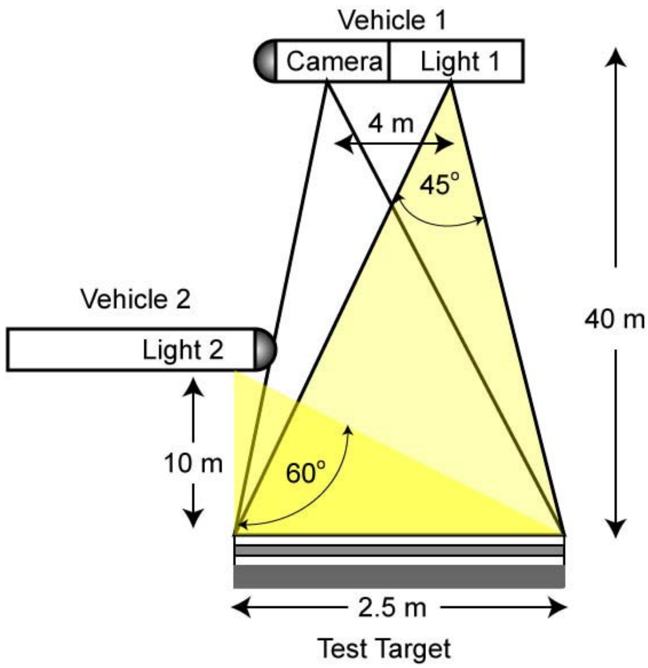

Figure 1. The geometry used to compare the potential performance increase possible with multiple vehicles. Shown are a single camera and 2 light configurations to be illuminated separately.

RESULTS

Input to the UNCLES program consists of both environmental parameters (IOPs) in addition to the needed AOPs (PSF) that is appropriate for a given underwater environment. In this example a moderately good imaging environment was selected that corresponds to coastal imaging. Values for a, b, and c were chosen to be .075, .075 and .15 inverse meters. Taking the reciprocal of the total attenuation coefficient c corresponds to the measure of total attenuation length, alternatively viewed as the distance over which 1/3 rd of the light penetrates without either scatter or attenuation. In this case, an attenuation length corresponds to 6.67 meters.

A target reflectance map was used that consisted of several horizontal lines with varying widths. A target size of 2.5 meters squared was chosen as well. The camera location was fixed for the two sets of simulations at an altitude of 40 m, corresponding to a distance of almost 6 attenuation lengths from the reflectance map to the camera. This distance would ordinarily be considered to outside the realm of what a traditional underwater imaging system might be capable of. However, as shown below, the new type of configuration seems to hold promise for achieving superior acquisition of images over ranges that were previously thought to be unobtainable from these traditional camera light configurations.

Figure 2 and 3 show a set of images collected with the system for the two different configurations. Figure 3, corresponding to both camera and lights located on the same vehicle, demonstrates that, as

expected, the small baseline and the long two-way distance for light travel renders the image useless. As shown, the image consists mostly of backscatter that has no information about the sea floor or target itself.   Figure 3, taken from the case where the source is placed on a lower vehicle demonstrates that a much clearer image is available via illuminating the target from this closer range

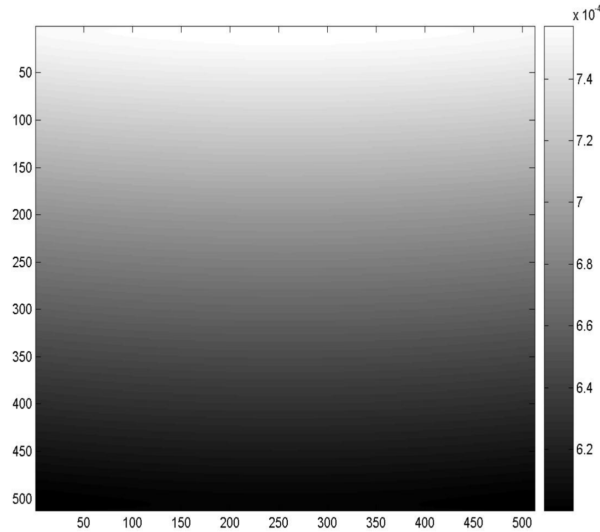

Figure 2. The predicted UNCLES image acquired by the camera in the geometry of Figure 2 when illumination is due to light source 1.

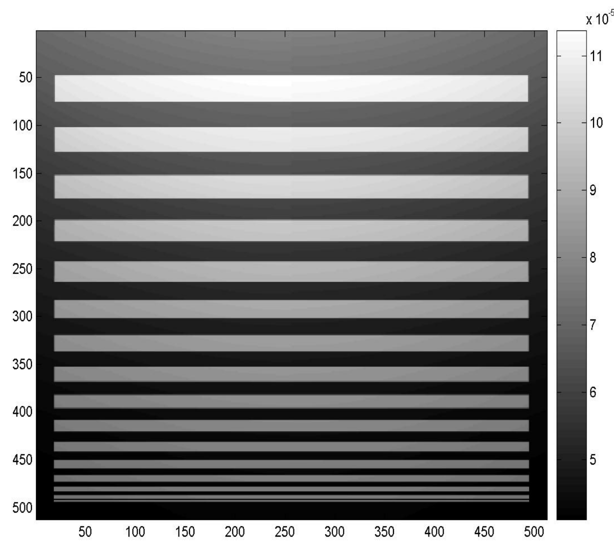

Figure 3. The predicted UCNLES image acquired by the camera in the geometry of Figure 2 when illumination is due to light source 2.

A more thorough analysis of the images considers not only their appearance but also the relative strengths of the different components that contribute to the image. It is helpful to look at these ratios because in some situations the use of high dynamic range recorders can increase image appearance via digital signal processing techniques. The UNCLES program separates the observed image into a number of additive components. The direct component is the light that has been reflected from the

target that does not incur any additional scatter on its way back to the camera. This is the primary signal component in underwater optical imaging. The blur component consists of the light that incurs forward scatter after reflection from the target that is subsequently imaged. In some cases (mainly shorter distances) this component contains substantial image resolution and can be considered as signal. Here, the target is at such a great range from the camera that inspection of this component led to the conclusion that this component contains no information. Finally, the backscatter component is the light that is scattered from the volume with no contact or information about the target. Table 1 displays the maximum value of these components for the two imaging scenarios.

Table 1. The image components due to both of the source locations

Component	Light1	Light2
Direct	2*10^-7	4*10^-5
Blur	1*10^-7	1.5*10^-5
Backscatter	1*10^-4	6*10^-5

Inspection of the table reveals that when the source and receiver are located on the same vehicle the backscatter component is almost 3 orders of magnitude higher than the signal (the direct component). On the other hand, when the source and receiver are located on different vehicles the direct component is almost as large as that due to both the blur and the backscatter. This leads to a very clear image as demonstrated. Although these results are not inconsistent with previous knowledge of underwater optical imaging and the advantages of different configurations it is clear that the arbitrary positioning of sources and receivers afforded by AUVs opens a new realm of possibilities. We note that this vertical separation would be difficult to achieve for any vehicle.